

A Design Science Research Account of System Architecture, Instructional Integration, and Evaluation in Animation Education

Nesamalar Damalingam¹, Ajmera Mohan Singh², Md Nagib Padil³

^{1,2}School of Social Science and Humanities, Lincoln University College, Malaysia

³Photography and Creative Imaging Department, College of Creative Arts, Malaysia

ABSTRACT: Hand-drawn and static media are the foundation of traditional animation and multimedia learning methods, which are restricted to students' capacity for cohesive visual storytelling and iterative experimentation. A virtual simulation storyboard system created utilizing the Design Science Research (DSR) technique with the phases of empathizing, defining, ideating, prototyping, and testing fills this need in Malaysian higher education. This article focuses on the artifact itself, which is, its functional architecture, the five stages of the interaction workflow from which the model originated, and the mechanisms by which each step was concretized as an actual system function of the EDIPT rather than the technology-acceptance model that was tested in the other sections of this research program. A quasi-experimental method (crossover trial) was used to illustrate and assess the system, comparing the experimental group using the system with a control group using traditional hand-drawing techniques. In terms of creativity, story coherence, and task completion efficiency, learners in the experimental condition were shown to be more creative, have greater story coherence, and spend less time on tasks than those in the conventional condition. The paper contextualizes these findings within the literature on learning technology, design thinking, and design science research. The article suggests that the key to making a pedagogy operational instead of being merely presented in a simulation environment is to embed an instructional cycle directly into its functional logic, not lay on top of generic software. The implications for creating immersive, creative educational technologies are discussed in this study.

KEYWORDS: Design Science Research, EDIPT, Design Thinking, Virtual Simulation, Storyboard System, Animation Education, Instructional Design

1. INTRODUCTION

Storyboarding serves as the skeleton of animation and multimedia. The organization of the story, camera logic, and composition of the visuals are all figured out before a single frame is completed. However, in the majority of Higher Education programmes in Malaysia, storyboard instruction is still being given as a hand-drawing session supported by the best static digital drawing tools. This method does not allow for iteration of exploration, experimentation with space or cinema and leaves narrative coherence up to the end of a storyboard, when it is too expensive to make changes (Bucher, 2017; Radianti et al., 2020). It has been proposed that immersive simulation-based environments would be pedagogically superior since they would allow learners to directly manipulate scene, character, and camera variables and observe the real-time consequences of the manipulation to their narrative and composition (Robin, 2008).

However, a large portion of the published evidence supporting this claim deals with learning technology as a black box. Whether students accept or use a system, or whether outcomes improve, the study focuses on the students or the outcomes rather than how the system was designed to represent a particular instructional logic. This is a significant gap since, in design-oriented fields, the research contribution itself is the artifact and the design reasoning (Hevner et al., 2004). While a technology-acceptance model can tell us whether a tool is functional, it cannot tell another designer how to create a functional tool on its own (Davis, 1989; Venkatesh et al., 2003; Blut et al., 2022; Xue et al., 2024).

That gap is filled in this article. It describes how an EDIPT-based (Empathize, Define, Ideate, Prototype, Test) virtual simulation storyboard system was designed and built for a larger mixed-method study on narrative quality and originality in Malaysia's animation sector. This article describes the artifact, but does not estimate a quantitative model of technology acceptance from the post-experimental survey results. Instead, it describes a problem framing, a functional architecture, how

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each stage of the EDIPT instructional cycle was translated into a concrete system function, and the comparative evidence gathered during the system demonstration in comparison to conventional instruction. The objectives of this article are to: (i) describe the virtual simulation storyboard system's functional architecture and design rationale; (ii) show how the EDIPT design-thinking cycle was incorporated into the system's interaction logic rather than serving as an external wrapper for the instruction; and (iii) summarize the comparative evidence of the system's demonstration from a quasi-experimental classroom trial (Micheli et al., 2019).

This article presents a design science account that emphasizes the artifact and its design logic, complementing the study's outcome-focused and acceptance-focused reporting, and provides other designers of immersive creative-learning technologies with a documented and theoretically grounded template for incorporating a design thinking cycle into the system's operation (Gregor & Hevner, 2013).

2. THEORETICAL BACKGROUND

2.1 Design Science Research in Educational Technology

Design science research (DSR) considers the development of a purposeful, measurable artefact, whether it be a system, method or model, as a valid contribution to knowledge in addition to the behaviour or explanations it provides (Hevner et al., 2004). Peffers, Tuunanen, Rothenberger and Chatterjee (2007) outlined this in a process which includes problem identification and motivation, setting up solution goals, design and development, demonstration, evaluation and communication. Despite the fact that the building processes of artefacts such as learning platforms, simulations and instructional systems are less often described in the same detail as their evaluation results, the technology of education has been slower to use the articulation of building processes in its research (Anderson & Shattuck, 2012). This article is organized according to the DSR process and it suggests that documentation of how an educational artefact is implemented in a pedagogical theory is as important to the field as documentation of whether it works.

2.2 EDIPT and Design Thinking in Creative Education

The design-thinking cycle adapted for storyboard learning from the widely-used cycle popularized by Brown (2008) is EDIPT (Empathize, Define, Ideate, Prototype, Test). Because of this iterative and user-centred approach, design thinking has been adopted to creative and technical education, where creative practitioners don't just go from planning to action, but rather bounce back and forth between understanding a problem, generating alternatives, creating something tangible, and then testing it out with the feedback from their users (Abd Manan et al., 2022). In animation education this translates directly to the process of storyboarding which includes empathizing with the audience or character, framing problems around the gaps in the stories, generating alternative visuals, creating prototypes of shot sequences, and testing and refining against the stories' coherence (Panke, 2019; Razzouk & Shute, 2012).

2.3 Virtual Simulation and Storyboard Learning

Previous studies have shown that virtual simulation environments increase learners' spatial cognition, design thinking, and creative fluency in comparison to static teaching methods (Radianti et al., 2020). Theory suggests that the qualities required for a storyboard are most closely aligned with the skills that are required for a simulation environment that allows learners to change and manipulate spatial relationships, camera framing, and continuity in a direct way, rather than by describing or sketching. However, far less has been published on how these environments' functional modules might be purposefully organized around a design-thinking instructional cycle rather than basic animation-software norms. This article addresses that specific design issue (Villena-Taranilla et al., 2022).

3. DESIGN SCIENCE RESEARCH PROCESS

The six DSR tasks of Peffers et al. (2007), problem identification, specification of solution objectives, design and development, demonstration, evaluation, and communication, were used to create the virtual simulation storyboard system. The mapping of these DSR phases to the EDIPT instructional stages, as well as to the corresponding activities of the research program and the artifact construction, is shown in Figure 1. This shows that the research program methodology and the artifact construction are presented as parallel rather than distinct phases.

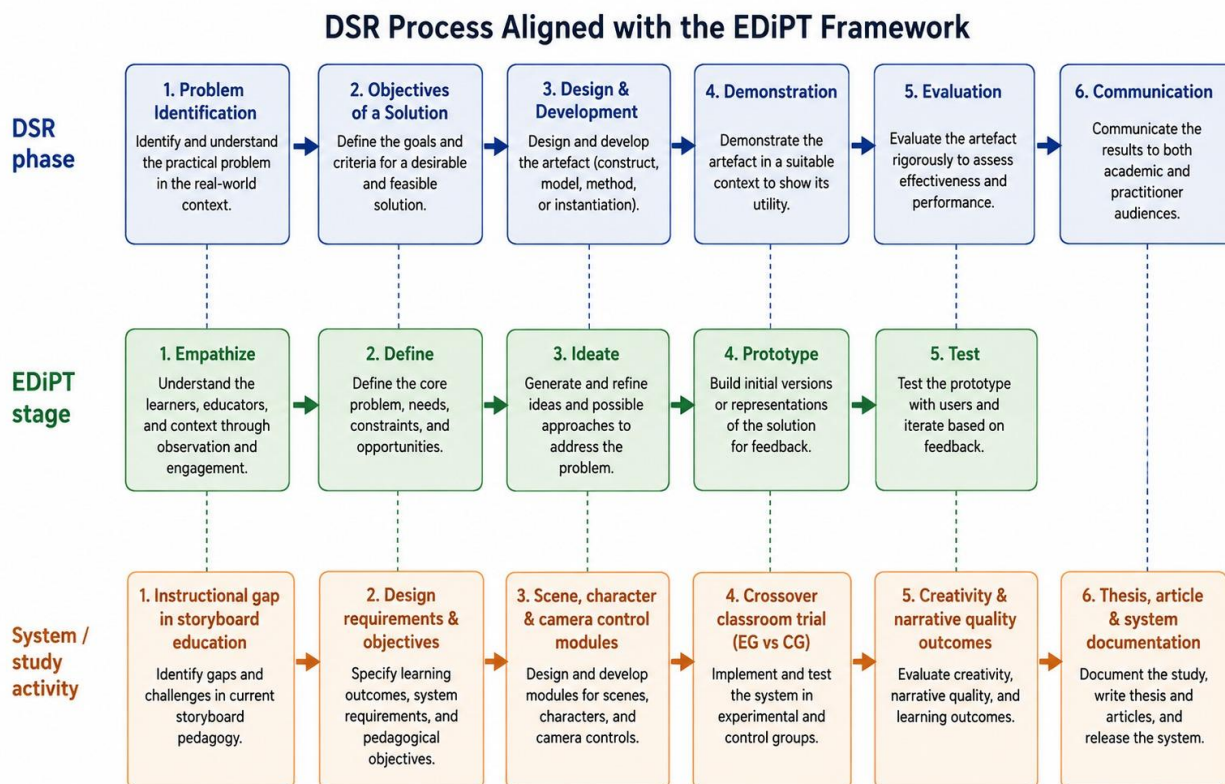


Figure 1: Mapping of the DSR process to the EDiPT instructional cycle and the system/study activities.

3.1 Problem Identification and Motivation

Even if the question is well-defined, it has to be precise and motivated by a strong argument. As previously mentioned, the initial challenge was that the current hand-drawn and static-digital storyboard instruction did not give students enough opportunities to evaluate their narrative and composition before making a final decision, nor could it allow students to explore, experiment, and discuss iteratively. This hinders the development of higher-order creative and narrative abilities that are intended to be fostered, as well as technical storyboard skills (Mayer, 2021).

3.2 Objectives of the Solution

From this problem, three objectives were formulated for the solutions. (i) the ability to directly create and manipulate the scene, the character and the camera perspectives; (ii) an iterative and revisable workflow that would allow the learner to test and rework his or her design decisions rather than leaving that aspect of the design to the instructor; and (iii) a structured learning cycle, EDiPT, embedded within the interaction logic itself, so that the use of the system would cause the learner to automatically follow the steps of empathy building, problem framing, ideation, prototyping, and testing in a self-directed way (Makransky & Petersen, 2021).

3.3 Design and Development

The objectives were put into action in the following research, which served as the basis for the Animated Script Virtual Simulation-Assisted Design Experiment, a 3D simulation environment created for storyboard development. Scene management, character control, camera control, storyboard creation, and file/export management are the five functional modules that were created and included in the system. These modules could all be accessible via the same project process (Hamilton et al., 2021).

4. SYSTEM ARCHITECTURE AND FUNCTIONAL MODULES

One design choice for the storyboard artist was represented by the system's functional structure: place, character, movement, how the frame is Shot, documenting and sharing of the resulting sequence. Table 1 provides an overview of the modules and the storyboard-design choices that each one makes (Jensen & Konradsen, 2018).

Table 1: Functional modules of the virtual simulation storyboard system.

Module	Core Function	Storyboard-Design Decision Supported
Scene Management	Selection and manipulation of 3D indoor/outdoor environments or imported picture scenes; object placement, rotation, and scaling	Establishing narrative setting and spatial arrangement
Character Control	Character selection, positioning, gesture and action configuration	Representing character intention and narrative interaction
Camera Control	Camera position, angle, framing, panning and zoom trajectories	Constructing shot composition and cinematographic perspective
Storyboard Generation	Conversion of configured shots into sequential storyboard panels	Translating simulated scenes into a reviewable visual sequence
File / Export Management	Project saving, editable source-file storage, and export to image/document formats	Supporting documentation, review, and downstream production use

4.1 Scene and Character Configuration

Users start a project by picking their 3D environment from a library of pre-defined indoor and outdoor environments, including classrooms, offices, parks and streets, or by importing their own image-based environment material. In the selected scene, objects can be selected, rotated, resized, and positioned by direct manipulation on screen. Characters can be positioned and given gestures, expressions, and motion patterns from a library of characters (Figure 2). This module implements the choices made in the scene-selection and character-configuration process, which would otherwise have to be redrawn from scratch in a conventional hand-drawn approach (Di Natale et al., 2020).



Figure 2: Scene management and character configuration interface. 3D classroom environment with an editable character and library panel.

4.2 Camera Control and Shot Composition

The camera-control panel is dedicated and allows users to move the camera, set its angle and position in the scene and also move it independent of any camera or scene settings, giving them the ability to make the shot composition a first-class design factor instead of a standard view (Figure 3). A camera module is a way to isolate camera manipulation from scene construction so that students can explore different ways the same scene and characters could be framed without having to rebuild the scene every time they need to compare different framings in the same scene (Parong & Mayer, 2018).

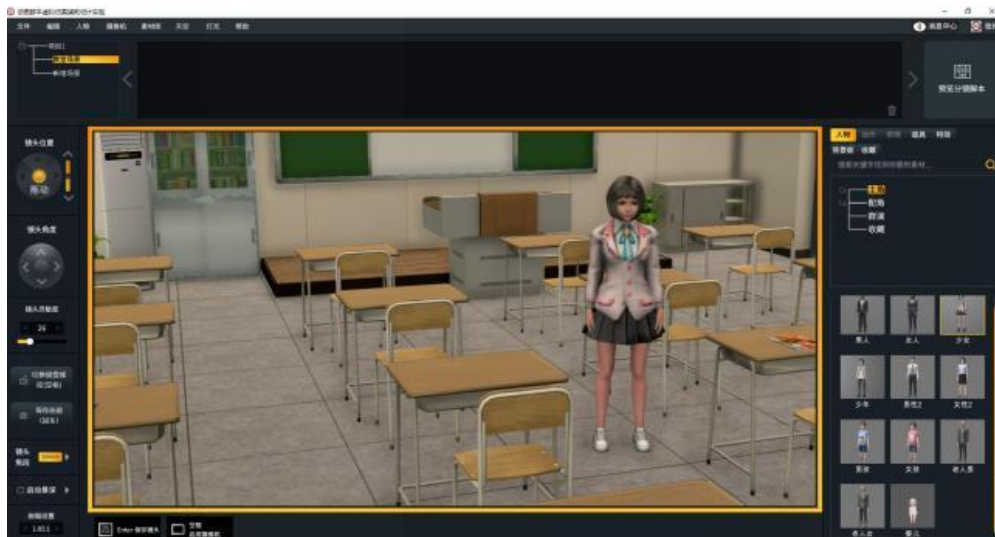


Figure 3. Camera control interface, showing adjustable camera position, angle, and distance controls alongside the framed scene.

4.3 Storyboard Generation and Export

After the shot is completed, the system transforms the set-up scene into a storyboard panel and builds up a series of panels into a storyboard. The finished sequence can then be exported in a selected image format and paper layout, along with the original scene, character and camera parameters for re-editing (Figure 4). This completes both stages of simulation to deliverable. The same interaction that allows a learner to experiment with a scene also provides the documentation artefact for review and critique, and for production handoff (Robin, 2016).

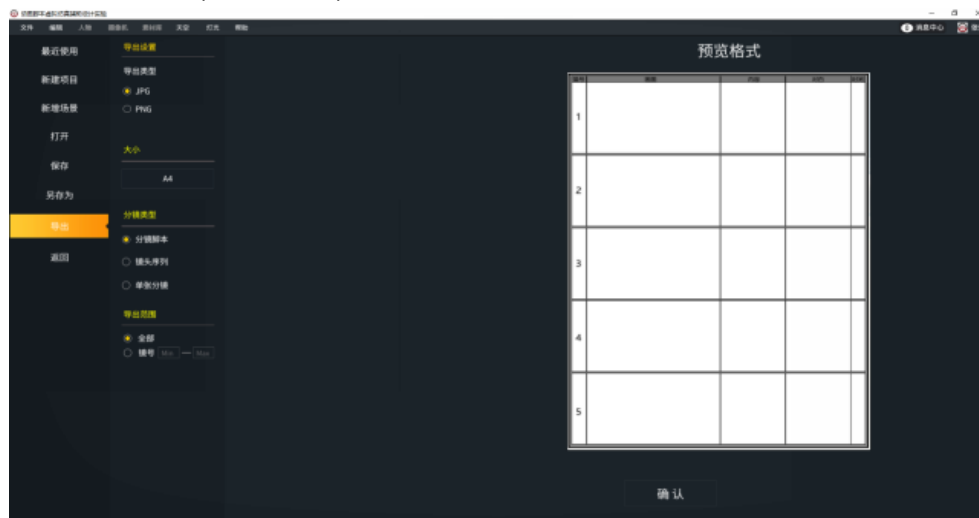


Figure 4: Storyboard export interface, showing panel layout, format, and range settings prior to generating the final storyboard document.

4.4 System Menu Architecture

These modules can be reached in a single menu structure that includes project and file management, editing tools, a character and material library, camera control, lighting, environment, and help functions. The menu structure ensures that all the functions are related to specific stages of the storyboard process, and that the purpose of the function is apparent from where it is found on the menu, as opposed to being placed in any menu that might be found in a general-purpose animation or drawing tool (Bond et al., 2020).

5. THE FIVE-STAGE INTERACTION WORKFLOW

The system employs a five-stage work pattern in each of the four aforementioned modules to direct each project from project start to export:

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Stage 1: Scene selection and project initialization - In order to define the plot setting where actors will move and shots will be made; users start a new project and choose a scene (Bruner, 1991).

Stage 2: Action Configuration and Character Selection - Before the production process proceeds, users may test the story logic by selecting the characters and adjusting their movements, gestures, and actions to transform that static script into an interactive visual prototype (Markowitz et al., 2018).

Stage 3: Shot composition and camera movement - In order to simulate effects that would ordinarily need to redraw numerous copies of the drawing for, users establish the camera angle, the framing, panning, and movement, and build the perspective of a tale in visuals (Calvert & Hume, 2022).

Stage 4: Storyboarding and Shot Saving - Finalized shots are saved and automatically converted into storyboard panels, which reduces the amount of human writing and facilitates review and modification (Luo et al., 2021).

Stage 5: Exporting scripts and saving files - Projects can be exported into a specific format for production usage, documentation, or collaborative review, or they can be kept for later change (Liu et al., 2020).

The procedure is not modular and is purposefully progressive: Choose scenarios, create characters and interactions, create storyboards as an artifact, fine-tune the visualization with camera configuration, and export for later usage. Importantly, the workflow is not linear in practice. Instead, each step is editable, allowing a learner to revisit a previous step, modify a decision, and then re-run and re-export subsequent outputs. This allows the workflow to support actual design experimentation rather than a predetermined software path (Makransky et al., 2019).

6. EMBEDDING EDIPT WITHIN THE SIMULATION ENVIRONMENT

Although the five-stage workflow is not based on the EDIPT instructional cycle, each step of the cycle is mapped to particular system affordances so that using the software would enact the cycle rather than the teacher imposing it (Merchant et al., 2014).

Empathize - Before any construction work starts, learners engage with the simulated scene and character library, interpreting the characters' intentions and the audience's point of view. The scene-and-character browsing and preview helps in this context, making empathy more of a "discovery" than a "thoughtful" exercise.

Define - Before beginning any building work, learners are then required to examine a first scene setup and, using the system's review and preview features, identify particular faults presented by the scene, such as poor narrative flow, abrupt transitions, and inefficient framing.

Ideate - Students may come up with and analyze many options for the same beat in the tale by arranging the scene, character, and camera modules in any way. Because reconfiguration occurs quickly, the method lowers the cost of investigating various concepts (divergent exploration) (Runco & Acar, 2012).

Prototype - While they are still defining the sequence, learners can experience it as a visual product rather than simply a conceptual plan due to the storyboard generation feature, which turns a group of specified shots into an actual, visible result.

Test - Because each step may be exported and revised at a later time, students can test a storyboard for narrative and visual coherence before returning to earlier stages to edit and re-generate, closing the loop from testing to further ideation and prototyping.

This mapping differs from other general storyboard or animation applications made for teaching since it incorporates the instructional cycle into what a student may accomplish at each of these stages rather than adding it after the fact through lesson planning (Pellas et al., 2021).

7. DEMONSTRATION AND EVALUATION

7.1 Quasi-Experimental Crossover Design

The artifact was tested in a realistic environment and against the goals it was designed to achieve, as advised by DSR (Peppers et al., 2007). In this case, a quasi-experimental crossover design was employed with intact classroom groups, which is ideal in many educational contexts where learner randomization is challenging (Shadish et al., 2002; Creswell & Creswell, 2018). Students were educated to utilize a virtual simulation storyboard system in one condition (experimental), while a comparative group (control) was taught to use a traditional hand drawing storyboard system. In a subsequent phase, the teaching was switched

such that both groups experienced both of these. By reducing the impact of variations in past skill level and individual learning experience, this within-subject exposure improves the comparison's internal validity (El-Masri & Tarhini, 2017).

7.2 Comparative Outcomes

For every dimension that was measured in terms of storyboard performance, learners in the experimental condition continued to perform better than the learners in the control condition across the dimensions of storyboard quality: creativity development, narrative coherence, visual composition, technical execution, and task-completion efficiency. Their storyboards were more original in concept generation, the sequencing of narrative beats was more coherent and consistent, and their emphasis on cinematic framing, continuity of the shots and character expression was closer to the conceptual side of visual execution, suggesting a closer integration of conceptual understanding and visual execution. Again, experimental-group learners had less time spent on storyboard tasks than control-group learners, consistent with reduced cognitive load, as manipulating pre-built scene and character elements and camera elements appears to free capacity for the learner to make decisions regarding narrative and composition.

These comparative results are consistent with constructivist and experiential learning theories, which believe that learning is more successful when students are exposed to meaningful, interactive, and context-rich learning environments (Kolb, 1984). They are also consistent with creativity theory constructs, which support learning environments that encourage experimentation, autonomy, and iterative learning (Amabile, 1996; Zhou & George, 2001). Furthermore, results corroborate earlier research showing that immersive, simulation-based learning settings are superior than static learning environments in terms of fostering spatial cognition and creative fluency (Radianti et al., 2020) (Runco & Jaeger, 2012).

8. DISCUSSION

8.1 Contribution to Design Science Research in Educational Technology

The example in this study illustrates a general concept regarding DSR in the realm of educational technology where an instructional cycle may be integrated into an artifact's interaction logic rather than being a structure that is added to it. However, the simulation environment's affordances, which enable an empathize-define-ideate-prototype-test cycle to be practically enacted within a single class session, are more likely to be responsible for the comparative advantage in Section 7.2 than the EDIPT term. The description of the learning system's functional architecture, in the context of mapping the pedagogical architecture is not a mere detail, but part of the causal explanation of why this learning system impacts learning outcomes as stated in this article.

It's also important to note how this narrative illustrates how DSR is typically reported in the realm of educational technology. By portraying the artifact as a black box in its introduction, this piece sought to defy the tendency of the majority of the literature in this field, which concentrates on and highlights the outcome measurements. In this article, I demonstrate that the "build" and "explain" stages of DSR are not linear but rather constitutive of one another by following the five functional modules and describing how each constitutes a design function as a particular system affordance. Only when the design function is explained and its instructional rationale is articulated does the reasons behind a design decision become understandable. Because of this, it is advised that an architecture description with instructional mapping, rather than just the demonstration and assessment outcome, should be included in education reporting. This enables other researchers and developers to have a decision path that they can apply to their own artifacts, which is more portable than a performance statistic.

8.2 Contribution to Creative Pedagogy

The results indicate that the constraint that prevents the conventional pedagogy of storyboard and animation from moving forward is not conceptual, but more practical. If the method is hand-drawn, students can't afford to try out multiple sketches, they are too hesitant to explore options and settle for one storyboard before moving on to animation. The lower cost of reconfiguration seems to give learners more room to experiment, and this is the source of the creativity and narrative-coherence observed most likely.

This discovery also has implications for what 'creativity support' means in a simulation tool. It is tempting to credit the experimental group's gains to novelty or the use of new technology rather than a specific mechanism, but the design justification offered reveals a more specific explanation, a decrease in the marginal cost of modification. When you hand-draw your storyboard, you will be testing out an alternative stage or camera angle by redrawing numerous panels, so learners are more likely to make an initial judgment about their staging/camera angle and then defend it rather than question it. Because the scene, character, and camera modules are separate and readily editable by the learner, a student may maintain the tale consistent while experimenting with composition, or vice versa. This is consistent with the pattern, where the benefit for the experimental group was seen irrespective of creativity, coherence, and time-on-task - outcomes that are difficult to explain as an engagement effect, but accord

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with a true cost reduction for exploration. Read this way, that pedagogical claim is narrower and more testable than the general intention of "simulation improves creativity in general" in that it is the removal of the redrawing penalty that allows the EDIPT cycle to be enacted as opposed to just described to students (Ajzen, 1991).

9. IMPLICATIONS

9.1 Theoretical Implications

The system's evolution implies that design-thinking models like EDIPT are better understood and used as a specification for system functionality, rather than an instructional overlay that is added once a tool is created. The designers of other creative or design-based learning technologies might find it useful to draw on the mapping approach outlined in Section 6 to design a system to operationalize each of the steps in the selected model at the design stage, with the intent of defining which system functions will do so.

This has a special importance for evaluating design-thinking models as learning interventions. If a model, such as EDIPT, is only provided as a lesson sequence, that is, as a progression of empathetic, defining, ideating, prototyping, and testing, its effectiveness is difficult to distinguish from that of the teaching: a competent facilitator can make even the most unproductive of models appear productive. Having the cycle built in the interaction logic of a tool is one method to distinguish between the model's contribution and the facilitator's teaching since the affordances that enact each phase stay constant regardless of who is teaching. This makes the artifact more than simply a tool for delivering EDIPT; it also gives a chance to operationalize the model as a testable construct in its own right, which is not usually explicitly stated in previous design-thinking literature in creative education.

9.2 Practical and Design Implications

For instructional designers and developers creating comparable systems, three design choices in this system appear particularly pertinent. The system navigation is organized around the storyboard design process itself, rather than generic software menus, so that using the interface reinforces and does not obscure the design process; the scene, character, and camera manipulation components are separated and free to be re-combined as needed for development; and every stage is edited after exporting, allowing testing to inform further development.

In addition to the three design decisions outlined above, the narrative in Sections 4-6 proposes a broader design rule for developers creating similar creative-learning environments: the intent of the learning experience should be communicated through the interface's presentation and limitations, as well as the representations it displays. The menu layout, module separation, and the ability to alter earlier stages are more than merely interface options; they are either positively or adversely connected to a specific phase of the desired learning path. As a result, designers who try to replicate this approach in other creative areas (game level design, architectural visualization, or advertising storyboarding, to name a few) should first define their pedagogical model in terms of specific system functions before creating an interface to support that model, as shown in Table 1 and Section 6, rather than adding a pedagogical rationale to an already generic tool. By approaching the mapping exercise as a design specification rather than a rationale, the instructional cycle may be implemented within the system rather than merely being referenced in a handbook or lesson plan.

10. LIMITATIONS AND FUTURE RESEARCH

10.1 Contextual and Disciplinary Scope

The description given here is based on a single artifact and one instructional context: animation and multimedia storyboard education in Malaysian higher education. The functional architecture described in Section 4 and the EDIPT mapping in Section 6 were designed to suit the demands of storyboarding in the context of spatial staging, character intention, and shot composition. Even if the same basic EDIPT logic is transferred, the mapping between stages of instruction and phases of system operations varies in creative domains with various representational requirements, such as game-level creation, architectural walkthroughs, or advertisement design. The module design in this report should thus be treated as a working example of a method to creating a module for mapping, rather than a template to be followed without modification.

10.2 Limitations of the Demonstration Design

The quasi-experimental crossover trial described in Section 7 was chosen because random assignment within intact classroom groups is not practical, and within-subject exposure improves internal validity compared to a between-groups comparison. It is important to note, however, that crossover research cannot entirely remove carryover effects, which occur when the learner's performance in the first condition influences their performance in the second condition, regardless of which is presented first. The single-session demonstration provided here does not distinguish between improvements owing to system

affordances and gains due to exposure to a novel system. These two hypotheses may be distinguished more clearly in a more extended demonstration across numerous sessions, or in a randomized controlled experiment.

10.3 Duration and Persistence of Effects

The results in Section 7.2 only apply to immediate performance, as just one instructional session was recorded for the presentation. It is uncertain if the originality, coherence, and efficiency exhibited here translate to unaided hand-drawn storyboarding once the novelty of the simulation environment wears off, or if it is due to the employment of the simulation environment itself. It would be important to determine if the benefit shown in this study represents a persistent ability change over the course of a complete semester or a short-term effect of tool support owing to the single session employed for each group.

10.4 Attribution to Specific Design Features

The demonstration in Section 7 examined the system as a whole in comparison to traditional teaching and did not distinguish between the contributions of the five functional modules or any specific affordance in Section 6's EDIPT mapping to observed benefits. A controlled feature-ablation study (for example, comparing the full system to a version with camera control ablated and a version with earlier parts of the system ablated, and so on) would allow future studies to attribute results to the various design features rather than the system as an undifferentiated whole, providing more concrete guidance to other developers.

10.5 Comparison Against Alternative Instructional Models

This account does not contrast this mapping with how the same architecture as the EDIPT cycle might be supported by an alternative approach to instruction, such as ADDIE or SAM. Thus, the comparative evidence in Section 7 is a comparison of simulation with hand drawing, not one instructional cycle with another, and therefore does not speak to the question of whether it is EDIPT specifically, rather than structured iteration generally, that accounts for the advantage found. Future design-science efforts with the same artifact and producing parallel instructional mappings would help to know how much of the benefit is due to the EDIPT sequence.

10.6 Directions for Extension

Together, these constraints point to several concrete future directions: implementing an additional module-mapping in an adjacent creative domain to see if it is transferable; expanding the demonstration longitudinal to see retention rate; doing a feature-ablation study to see which affordances are responsible for the gains; and making a second instructional mapping for an additional architecture to compare their performance under the same conditions. One additional direction, consistent with the overall research program, is to look into the possibility of using adaptive or AI-based feedback during the storyboard generation and testing phases, allowing for a "Test" phase of the cycle to be conducted with system-provided feedback rather than relying solely on the learner's self-assessment or the instructor's evaluation of the learner's work.

11. CONCLUSION

This paper reported the design and development of virtual simulation storyboard system based on EDIPT as design science research artefact, the functional architecture, the five-stage interaction workflow and the design of the specific mechanisms of each step of the EDIPT instructional cycle embedded in the artifacts functionality, rather than layered on top of it. In a quasi-experimental crossover trial, it was discovered that the method can generate more creative and well-structured storyboards and job completion efficiency when compared to traditional hand-drawing instruction. According to the account, operationalizing the pedagogical model through the interaction logic of a learning technology is a crucial addition to outcome and acceptance-oriented evaluations. It also provides a model for other designers of immersive creative-learning technologies.

More generally, the value of any contribution to educational technology design science is the traceability of the design reasoning and the products it yields. The functional architecture and the EDIPT mapping presented in the report will allow a further researcher to appreciate that the system was not only more effective than traditional instruction, but also to determine how it was, i.e. in the way it reduced the cost of iteration, outlined in Section 8.2, and to see how this mechanism was engineered into the artifact, rather than simply assumed to follow naturally from the fact of giving students access to 3D tools. That is why the contribution of this article is set in a more focused manner than a general claim of virtual simulation: a documented, reusable method for translating a design-thinking cycle into the functional logic of a creative-learning system, which is offered as a template that other designers may adapt, test, and, as the limitations above indicate, extend, compare, and refine in contexts other than the one reported here.

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